Mapping the Chemical Composition of Subchondral Bone in Osteoarthritis Using Infrared Microspectroscopy

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Abstract No. chan8708
Beamline(s): **U2B**

Osteoarthritis naturally occurs in young adult female cynomolgus monkeys and it closely resembles the human disease. In the knee joint, it is characterized by the breakdown of the articular cartilage and marked thickening of the adjacent subchondral bone. There is a strong correlation between the severity of the osteoarthritic lesions and the thickness of the subchondral bone, but it is unclear why this is the case. We question whether the newly-deposited subchondral bone has a different chemical structure/composition compared to the older bone, leading to the development of osteoarthritis. Presently, we are using infrared micro-spectroscopy to study the chemical composition of the subchondral bone as a function of subchondral bone thickness. We are able to map the subchondral bone from the articular cartilage (older bone) to the marrow space (newer bone) and compare their chemical compositions. Bone proteins, primarily collagen, absorb infrared light in the 1450 - 1650 cm^{-1} region. An intense, broad band from 900 - 1200 cm^{-1} and a double-peaked band from 500 - 650 cm^{-1} are attributed to bone mineral, i.e. phosphate ions in hydroxyapatite. A small absorption centered at 875 cm^{-1} arises from carbonate-substituted hydroxyapatite. These bands are sensitive to mineral content (i.e. carbonate, phosphate, acid phosphate), mineral crystallinity, and the content/nature of the organic matrix. They are curve-fit and/or integrated and compared as a function of (1) state of the bone, i.e. thickness of the subchondral plate, and (2) age of bone, i.e. position in the subchondral plate.

To date, we find substantial differences in normal versus osteoarthritic monkey subchondral bone. Results demonstrate a significant difference in collagen structure in all animals with OA (mild and severe cases) when compared to unaffected animals. In addition, we observe an overall increase in the level of mineralization as a function of disease severity. In animals with severe OA, we find a dramatic increase in carbonate content. Since subchondral bone composition affects both the mechanical and physiological properties of bone, these results, along with additional studies of subchondral bone collagen metabolism and mechanical changes, may shed new light on the pathogenesis of OA.